Mesh Morphing Accelerates Design Optimization

RBF Morph and ANSYS FLUENT software combine to produce a solution for shape modifications through mesh updating.

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Executing Simulation Driven Product Development typically includes performing parametric studies (such as multi-configuration studies, sensitivity studies and design of experiments) in which a component's shape or position is updated to assess the impact on fluid dynamic, or in some cases structural mechanics, characteristics. A common approach for fluid dynamics is to update the initial geometry, remesh the entire domain and then rerun the analysis. A viable alternative in many cases is to modify the mesh and rerun the flow analysis without going back to the geometry step until the optimum configuration is determined. This requires using a mesh morpher tool.

ANSYS, Inc. software partner RBF Morph has developed such a tool that allows ANSYS FLUENT users to perform shape modifications through mesh updating. With RBF Morph technology, there is no need to update the geometry until after the final design is selected. The entire setup can be done inside ANSYS FLUENT software using a comprehensive interface that allows a user to define the morphing problem. Commands are available to drive the morpher by means of simple scripts. No additional mesh I/O is required, as the morpher acts directly during the parallel solving stage.

The most important requirements for high-fidelity mesh morphing are:

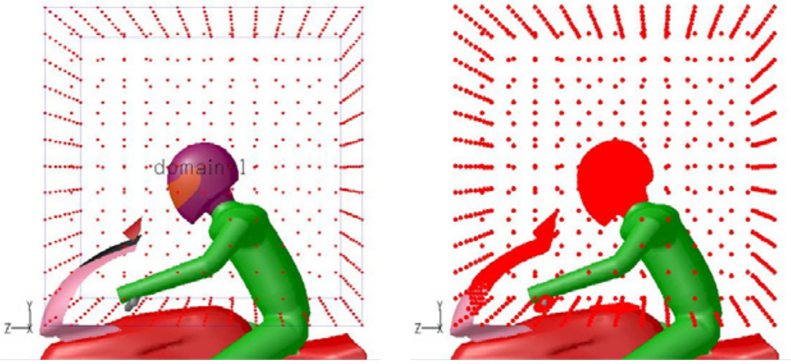
- Mesh-independent solutions
- Parallel morphing of the grid
- Ability to morph very large models (hundreds of millions of cells) in a few minutes
- Support for every kind of mesh element type (tetrahedral, hexahedral, polyhedral, prismatic, nonconformal interfaces, etc.)

RBF Morph satisfies these requirements using state-of-the-art radial basis function (RBF) techniques. RBFs are capable of interpolating a prescribed mathematical function, which is defined at discrete points within a domain, yielding exact values at these points. The behavior of the function between points depends upon the type of the mathematical function prescribed.

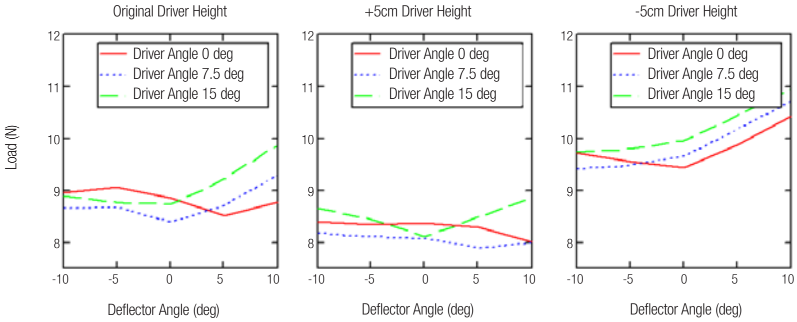
Mesh morphing with RBF Morph is executed in three steps:

- Setup and definition of the problem
- Solution of the RBF system
- Morphing of the surface and volume meshes

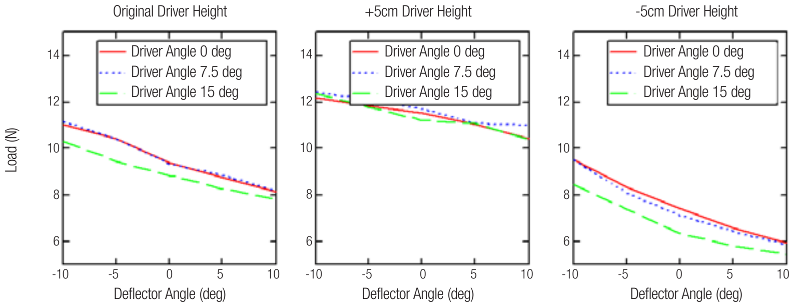
Mesh modifiers are prescribed in the first step, each with its own user-specified magnitude. (A scalar value sets the intensity of the modifier.) In the second step, the effect of each modifier upon the mesh can be



Setup step of RBF Morph. The morphed action is limited to the box region domain 1 (left). The motion of the surfaces inside the encapsulation domain (right) is introduced using the following constraints: windshield deflector (fixed), fairing (fixed) and helmet (moving).



Horizontal load on the helmet for each driver angle, plotted as a function of windshield deflector angle



Vertical load on the helmet for each driver angle, plotted as a function of windshield deflector angle

verified by previewing its action without actually moving the nodes. An undo capability can be exploited, allowing a user to verify resulting mesh quality and to update the setup if problems are found, such as negative cell volumes. The morphing operation in the last step can be performed in parallel, which is highly valuable when morphing large problems. It scales practically linearly.

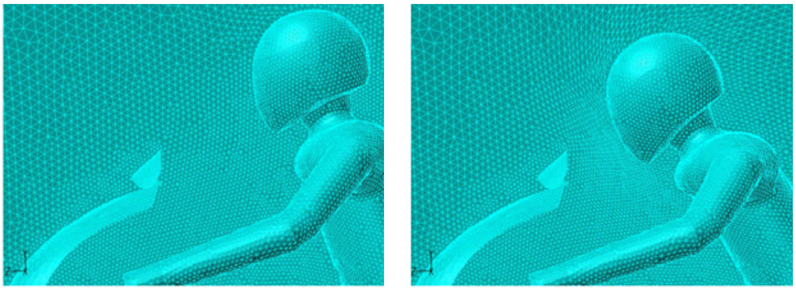
Considering that the modifiers are nonlinear and that large-scale mesh motion is involved, the effect of multiple modifiers upon the mesh depends upon their sequence of application. RBF Morph superimposes the effects of multiple modifiers using the same baseline mesh for the starting point of each modifier. Different sequences can be explored by the user through a comprehensive GUI, or programmed in a user-defined function. By applying mesh modifiers during the morphing operation, a parametric ANSYS FLUENT model results.

The working principles are highlighted with an industrial application example, the optimization of a motorbike windshield. In this study, three modifiers are used to change the original CFD model: driver height, driver position and deflector angle. Other modifiers can be defined and stored as well in a similar fashion. To allow for driver angle to be changed requires prescribing an encapsulation box. Grid density on the surface of the box may be specified. Only those mesh nodes that fall inside the encapsulation domain are modified by the morpher. To complete the setup, two more sets of source points are required: all the mesh nodes that belong to the helmet and all the nodes on the bike and windshield deflector. For the nodes associated with the helmet, a rotation about the driver is prescribed. For the nodes associated with the bike and the windshield deflector, a zero rigid movement is imposed to preserve the original shape. The remainder of the nodes that fall inside the encapsulation box remain free to deform under the action of the morpher.

The interaction between the prescribed modifiers is analyzed by means of a simple script that exploits the resulting parameterized ANSYS FLUENT model. Five windshield deflector angles (-10°, -5°, baseline, +5°, +10°), three driver angles (baseline, +7.5°, +15°), and three driver heights (-5 cm, baseline, +5 cm) are considered, resulting in 45 separate solver runs. By using RBF Morph, only one CFD model is needed to conduct the 45 runs, and execution of the runs is fully automated.

Results from this parametric study indicate that an improvement (for example, a reduction of load) can be obtained by varying the windshield deflector angle, while the optimum angle depends on driver height and driver position. Vertical load on the helmet is notably higher for reduced driver height. The horizontal load on the helmet is higher at increased driver height because of greater exposure to air flow, and this load decreases monotonically as windshield deflector angle increases. The effect of windshield deflector angle on total horizontal load acting on the driver behaves similarly to the behavior on the helmet.

RBF Morph software has proven to be very useful for a wide range of industrial applications like this one, successfully managing all of the desired configurations. ■



The mesh is morphed to vary driver angle between 0° baseline (left) and 15° (right), with respect to the vertical axis.

Reference

http://www.rbf-morph.com